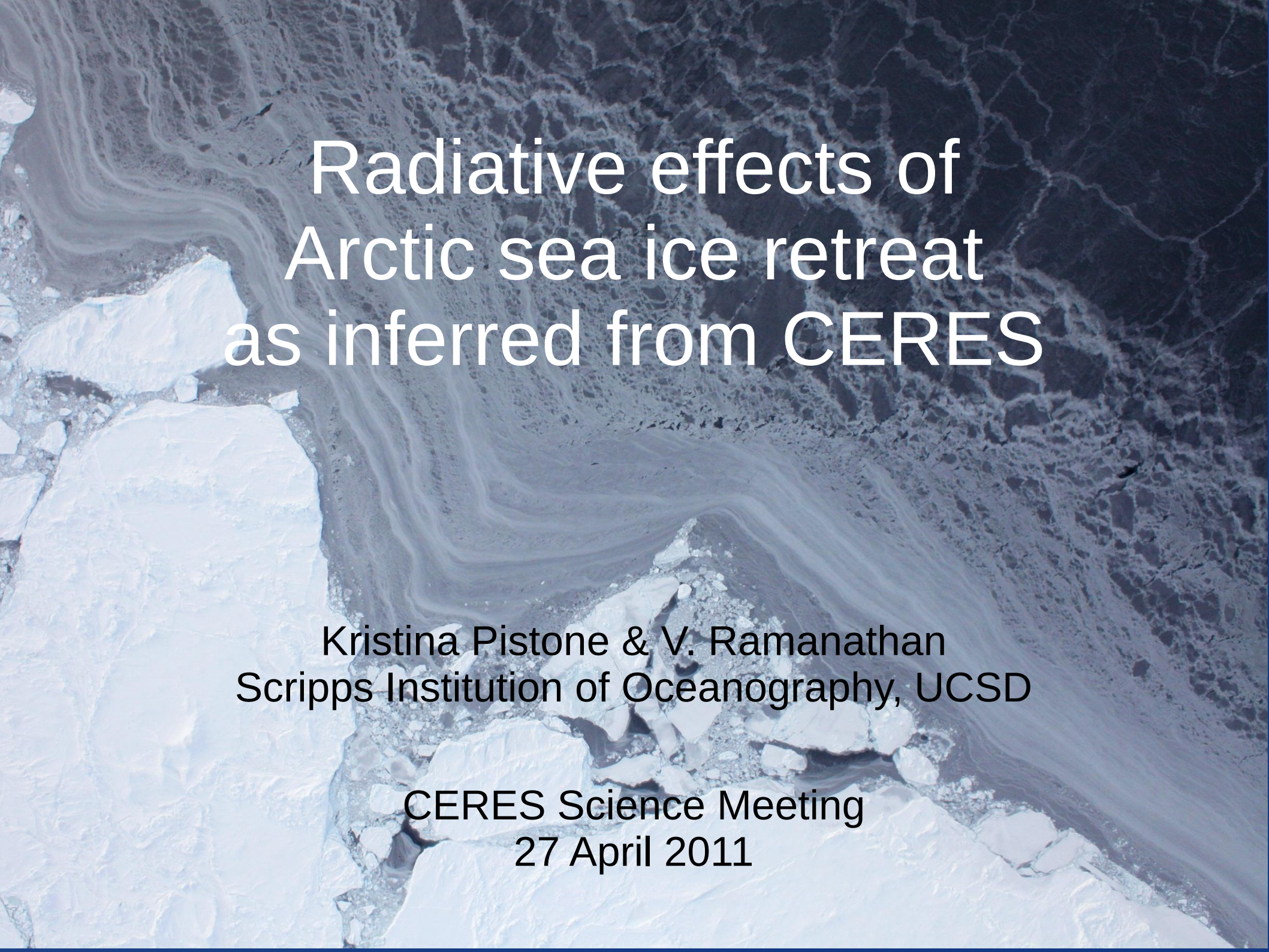

Radiative effects of Arctic sea ice retreat as inferred from CERES

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Scripps Institution of Oceanography, UCSD

CERES Science Meeting
27 April 2011

Objectives

Understand the albedo effects of sea ice retreat -- how much of an increase in solar absorption results from melting of sea ice?

Determine role of sea ice albedo feedback

Outline

- Overview: historic sea ice retreat
- Linear response of CERES clear-sky albedo to changes in sea ice
- Estimate of longer-term radiative effects and changes with time
- Ice albedo feedback: linear correlation with surface temperature
- Conclusion

Arctic sea ice retreat trends

- Three smallest September sea ice extents occurred in the past four years (2007, 2008, 2010)
- Three smallest amounts of (thicker) multiyear ice on record also in the past four years
- Eight of the ten lowest summer minimums recorded were in the last decade

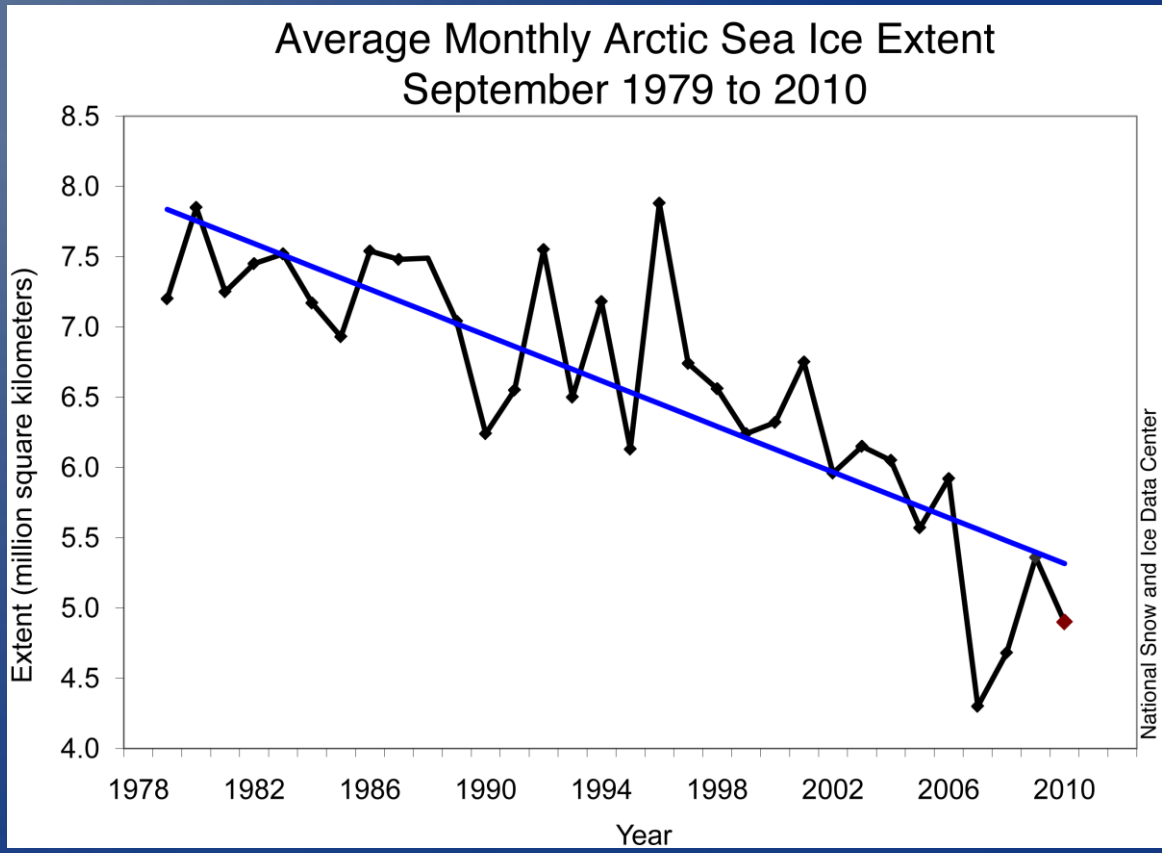
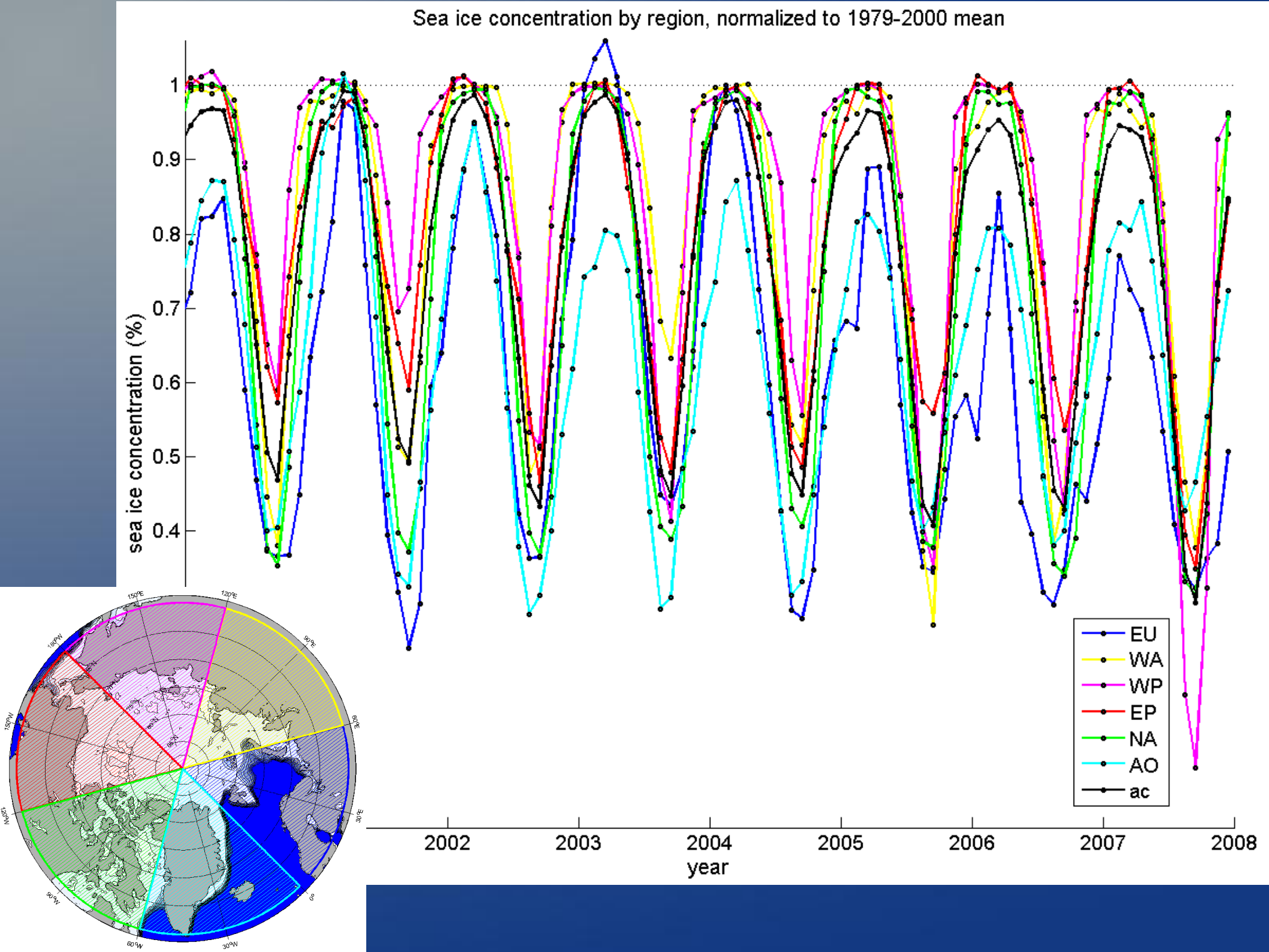
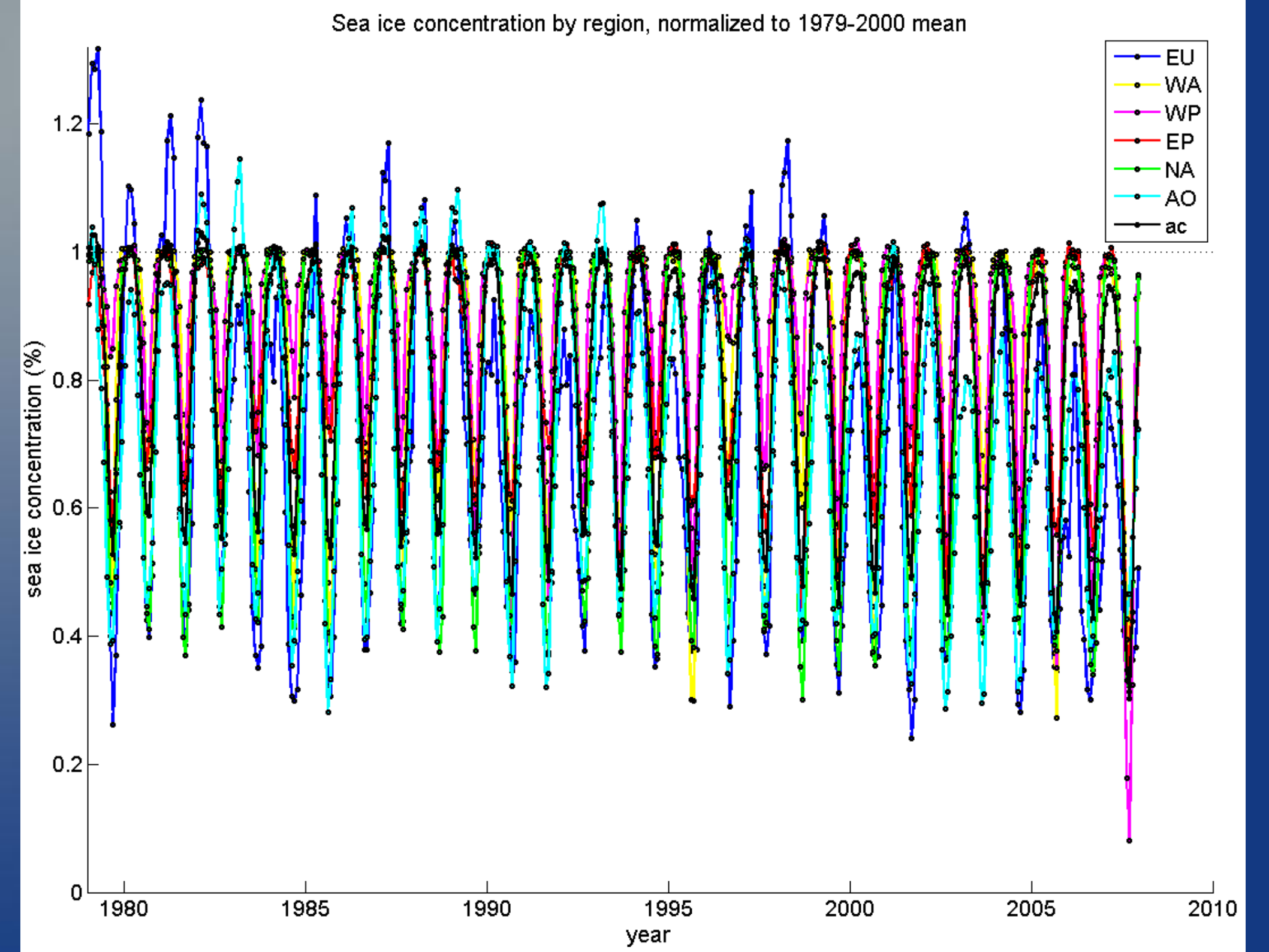


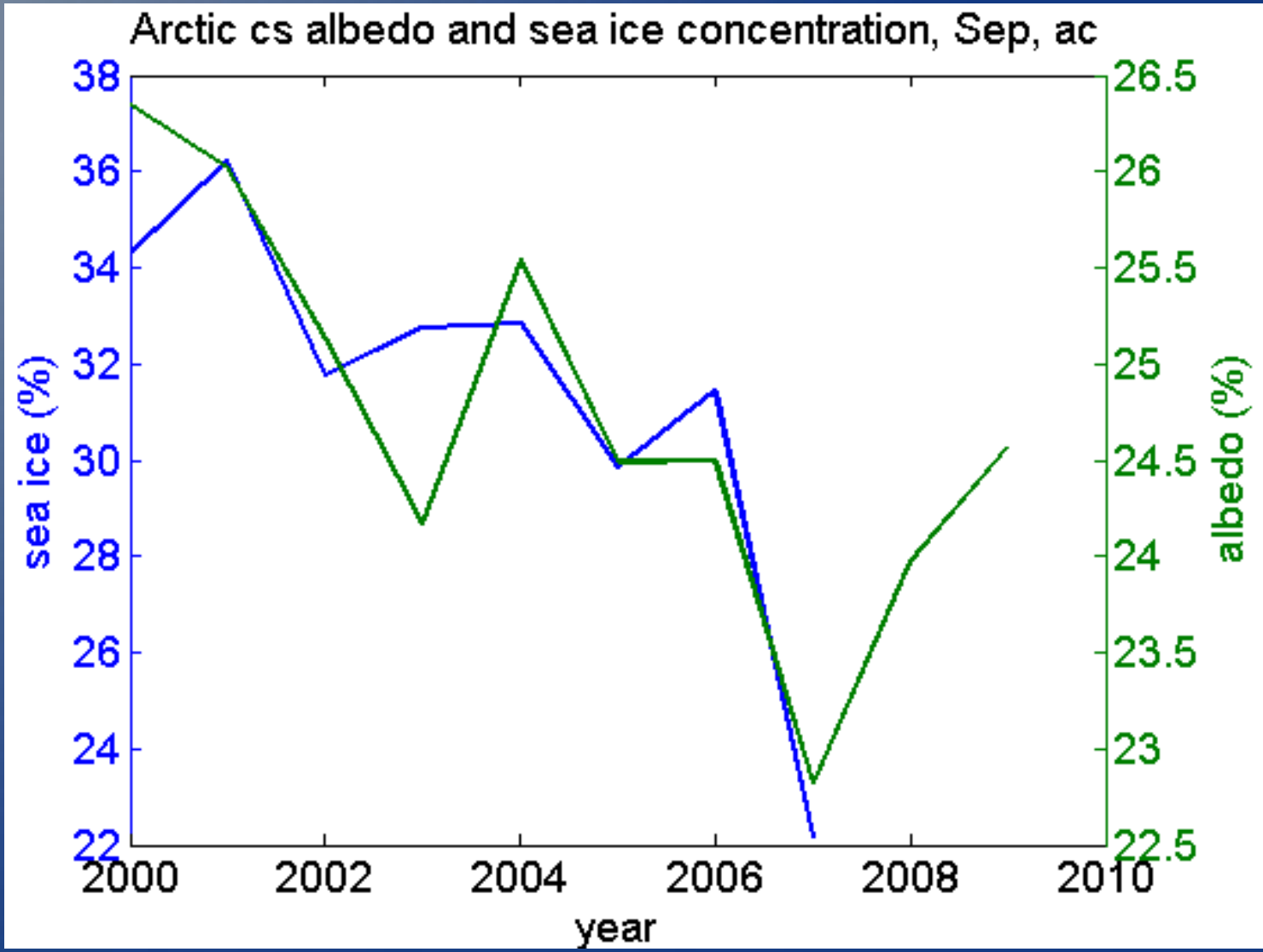
Figure credit NSIDC sea ice news: http://nsidc.org/arcticseaicenews/2010/100410.html
2010 Arctic Report Card: http://www.arctic.noaa.gov/reportcard/ArcticReportCard_full_report.pdf


Sea ice concentration by region, normalized to 1979-2000 mean
sea ice concentration (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
2002
2003
2004
2005
2006
2007
2008
year
EU
WA
WP
EP
NA
AO
ac


Sea ice concentration by region, normalized to 1979-2000 mean
EU
WA
WP
EP
NA
AO
ac
sea ice concentration (%)
year
0
0.2
0.4
0.6
0.8
1
1.2
1980
1985
1990
1995
2000
2005
2010

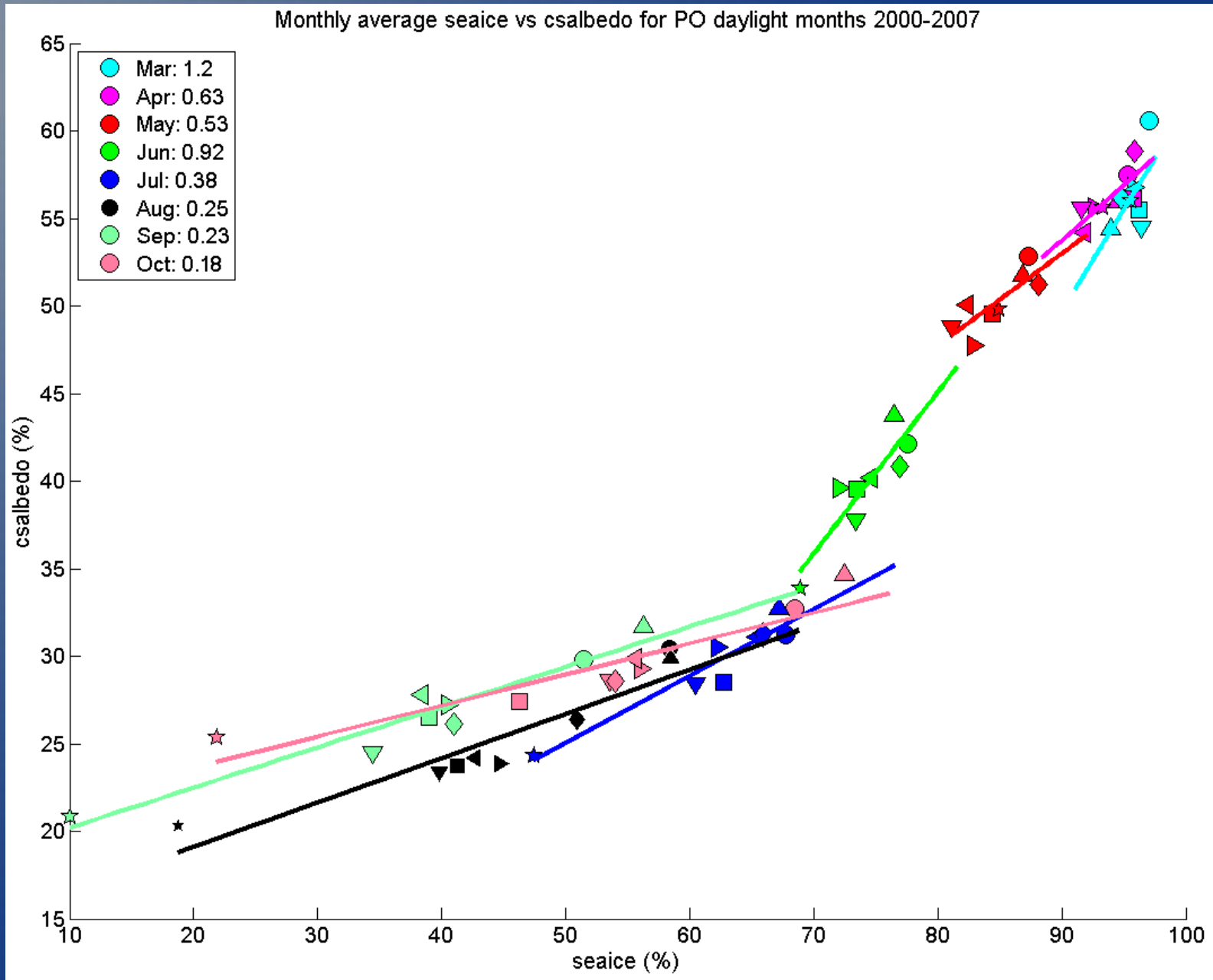
Sea ice and albedo

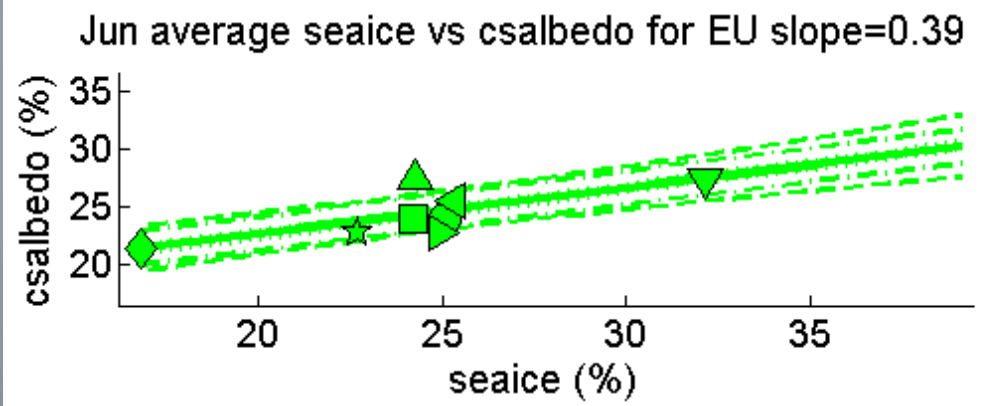
- In the overlapping time period, the trends of sea ice concentration and clear-sky albedo are concurrent

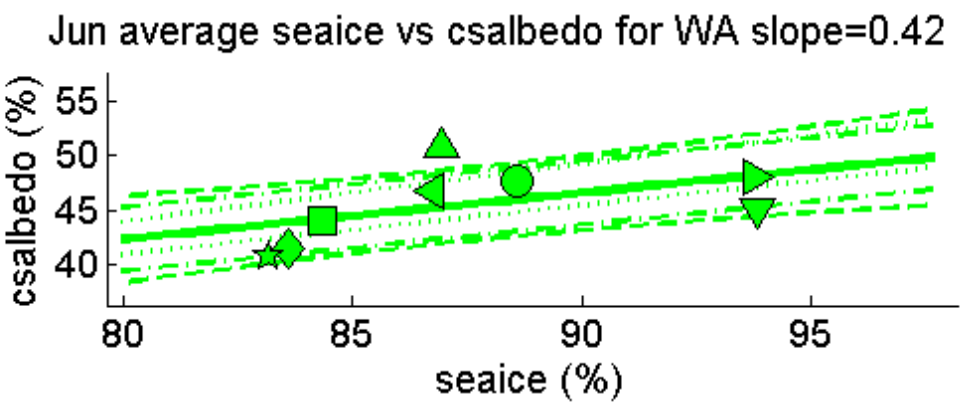


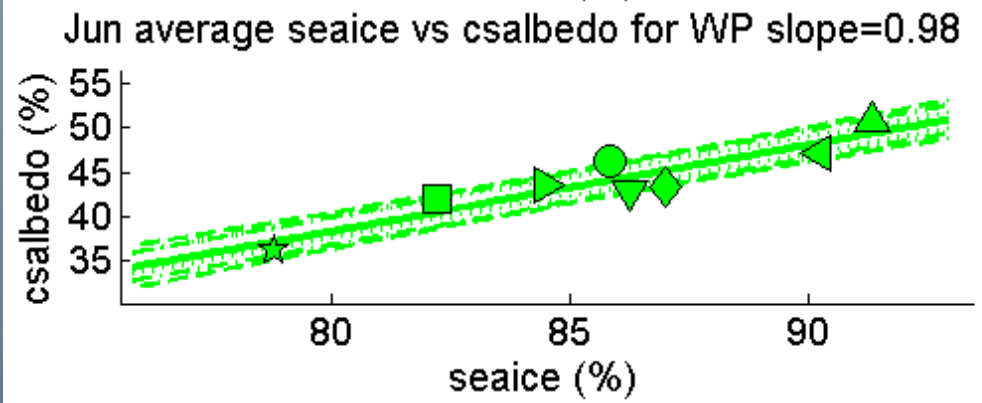
Clear-sky CERES albedo vs sea ice

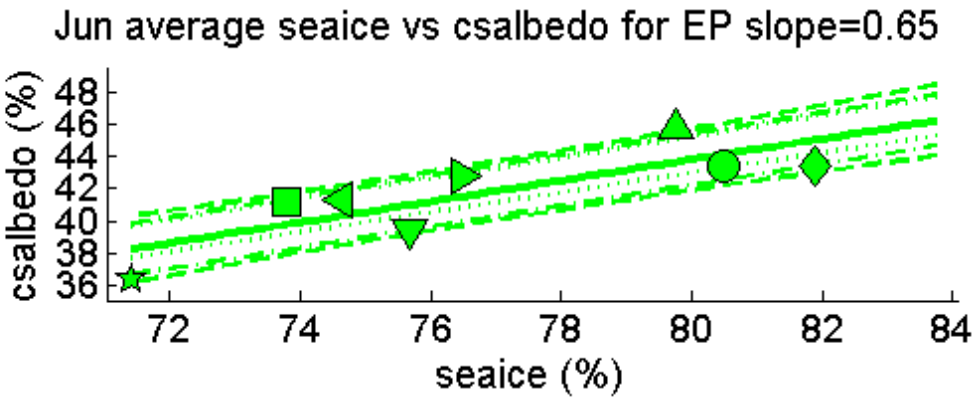
- Clear-sky values show clear linear trend with season
- Linear best-fit is dependent on month...

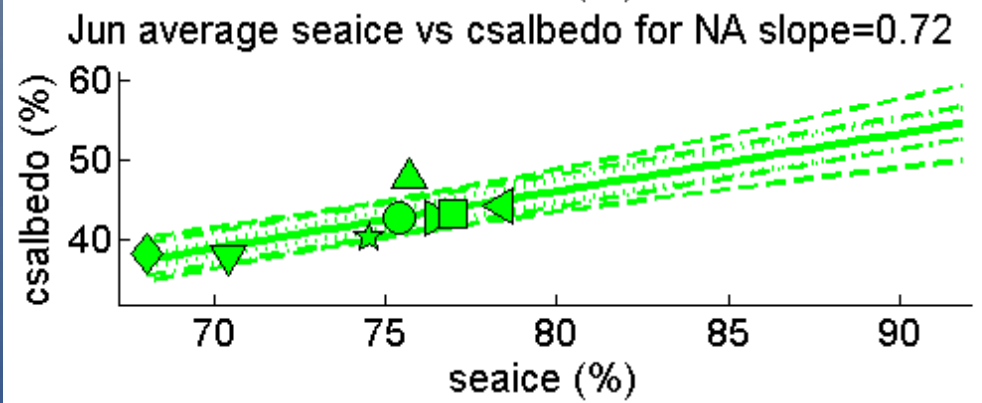


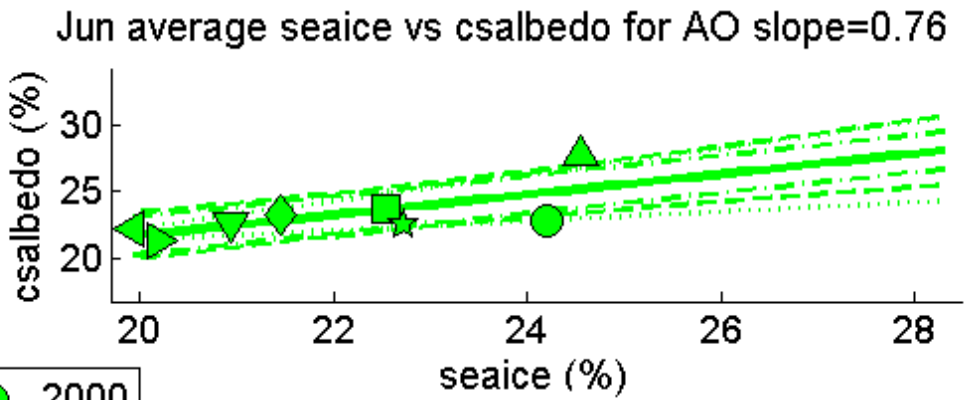


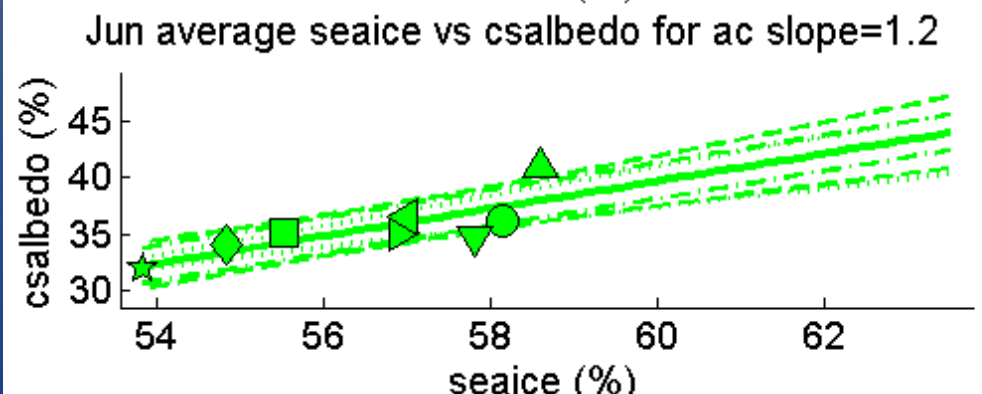


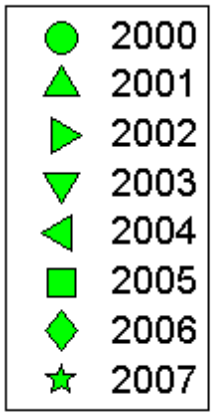






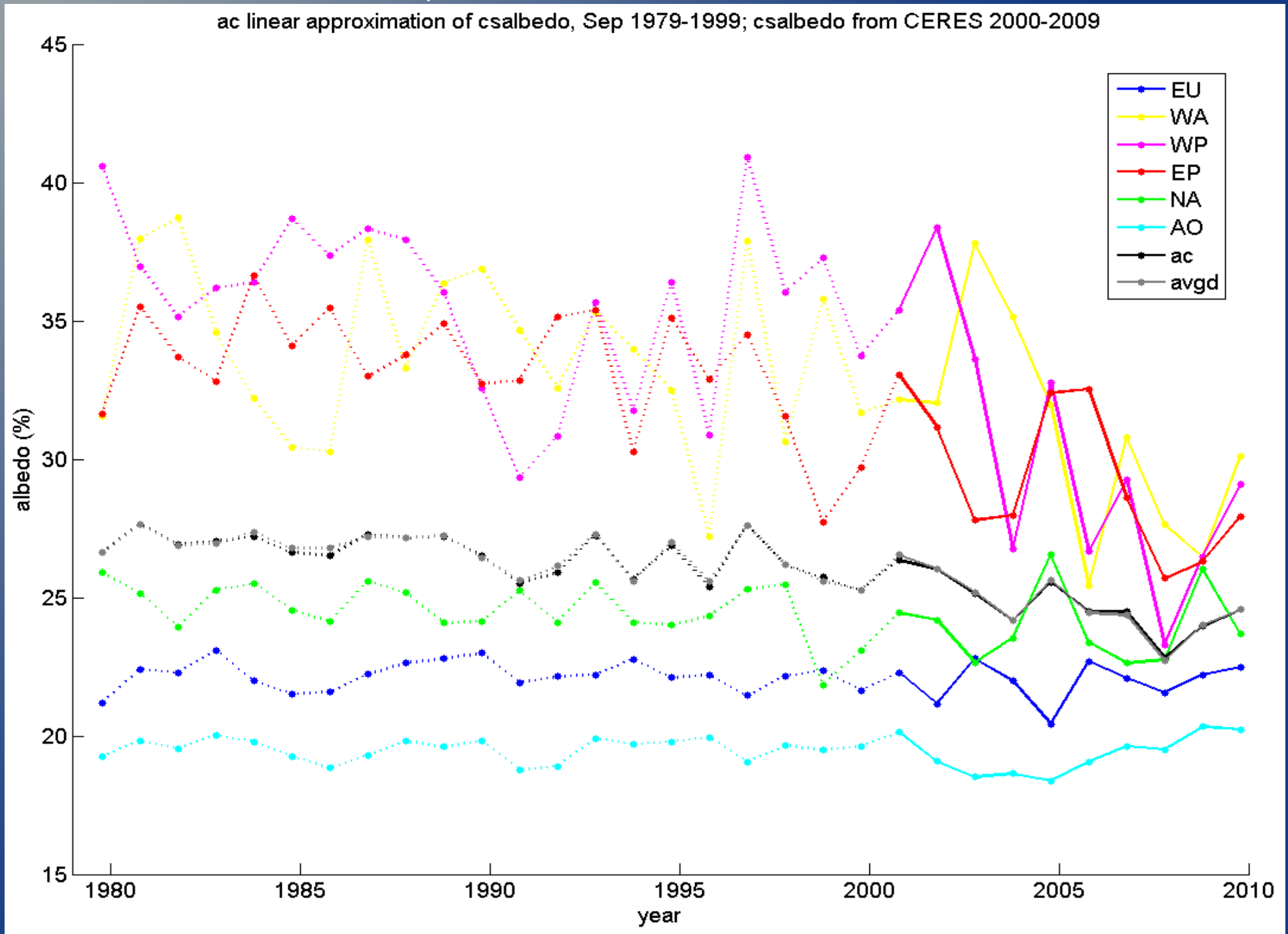


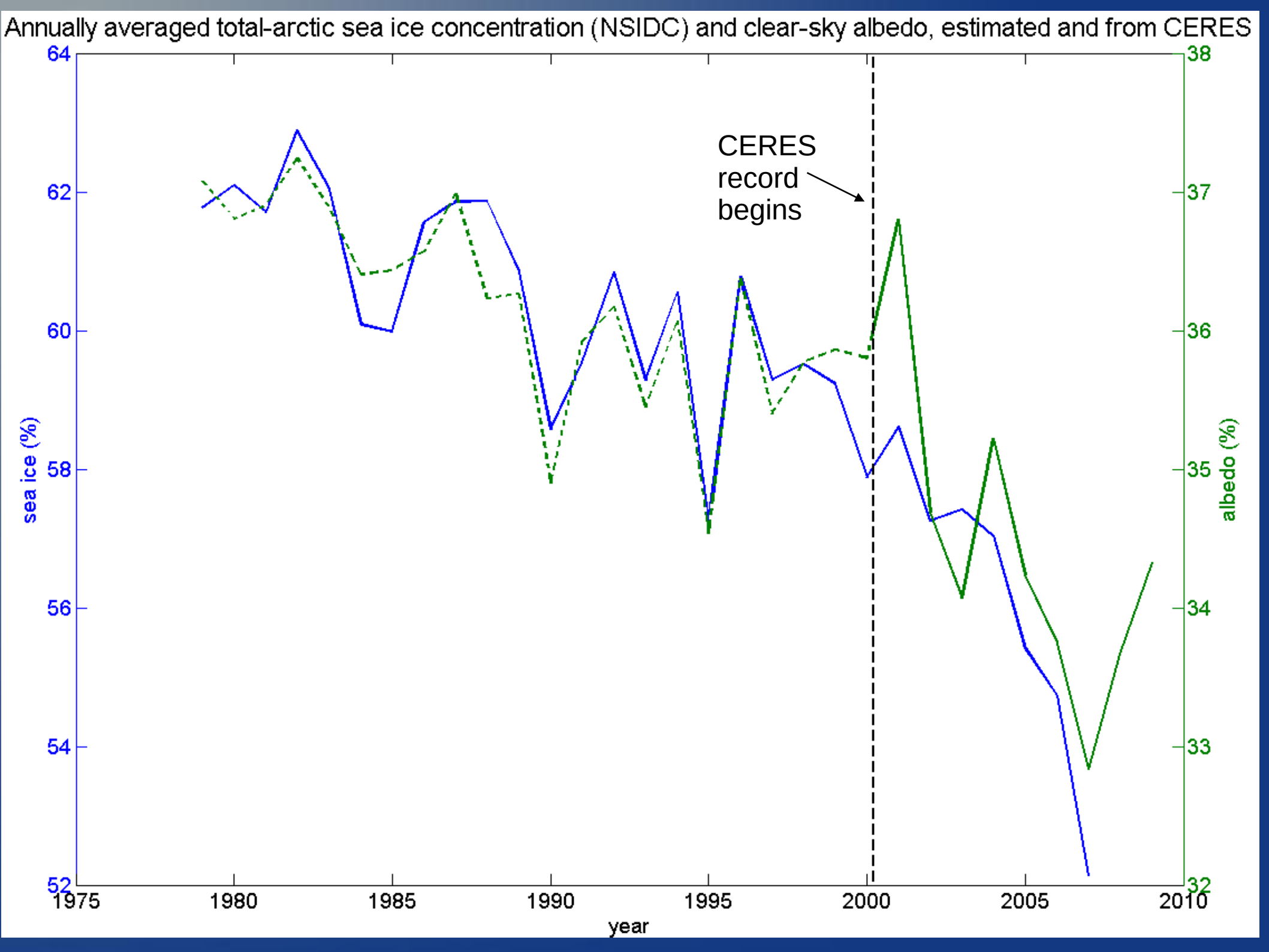




...and on region

From linear fits, construct historical albedo record

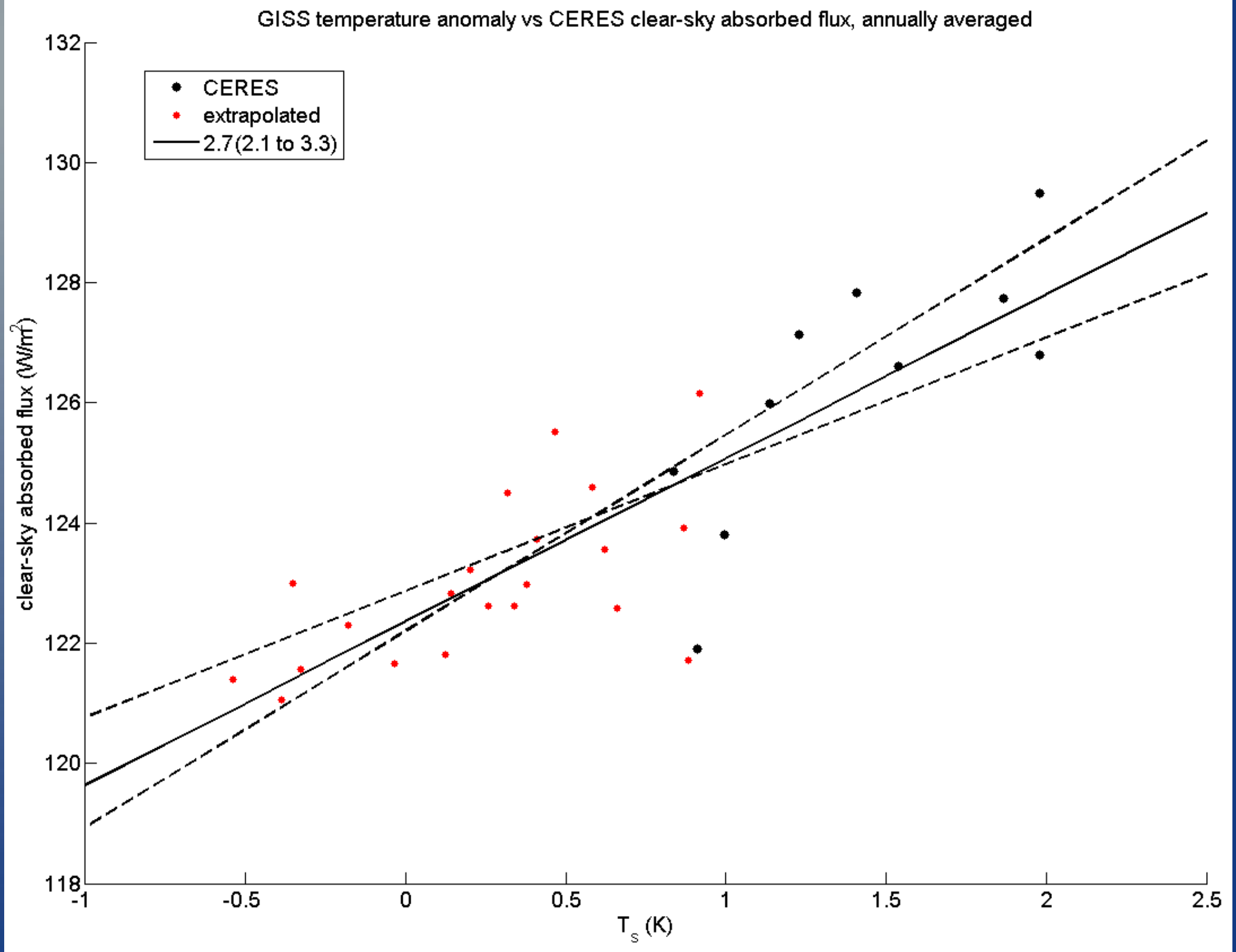


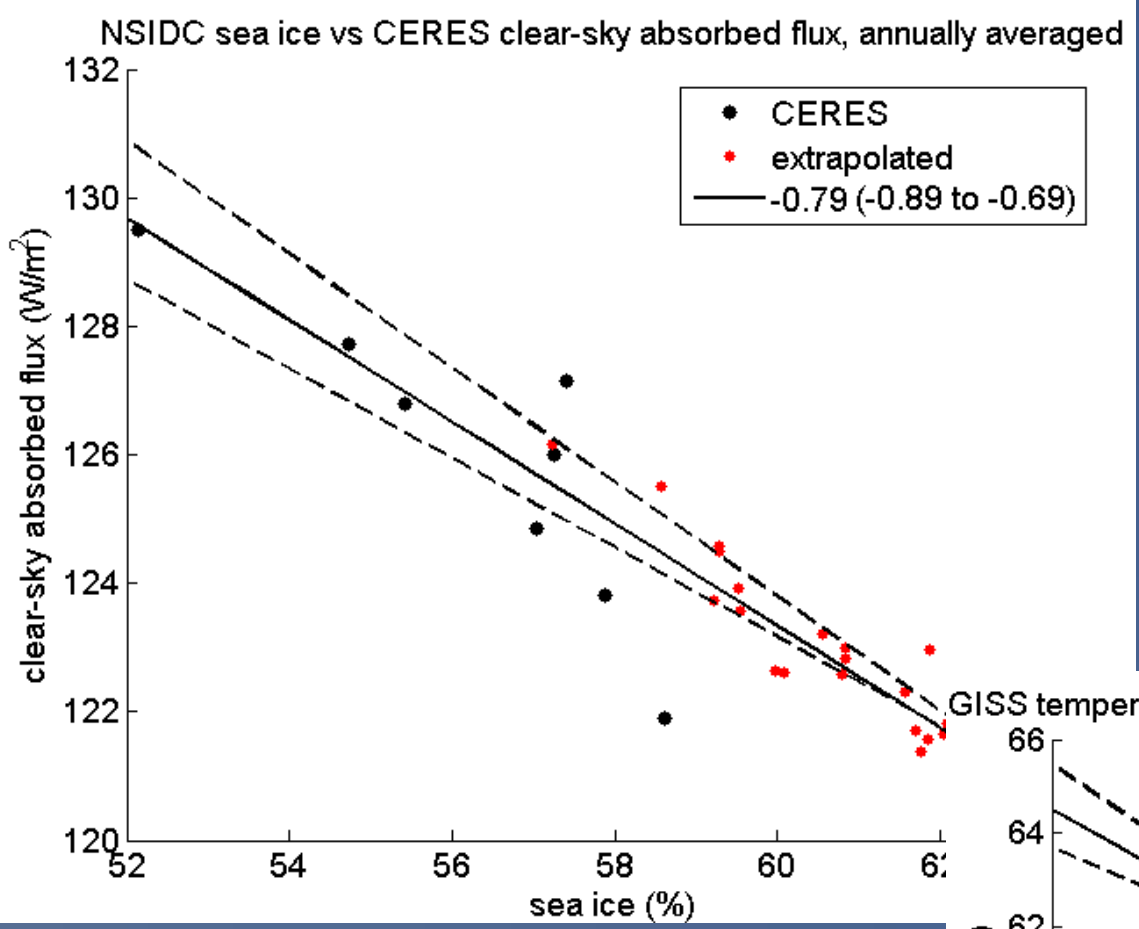

Annually averaged total-arctic sea ice concentration (NSIDC) and clear-sky albedo, estimated and from CERES
CERES
record
begins
sea ice (%)
albedo (%)
year
64
62
60
58
56
54
52
38
37
36
35
34
33
32
1975
1980
1985
1990
1995
2000
2005
2010

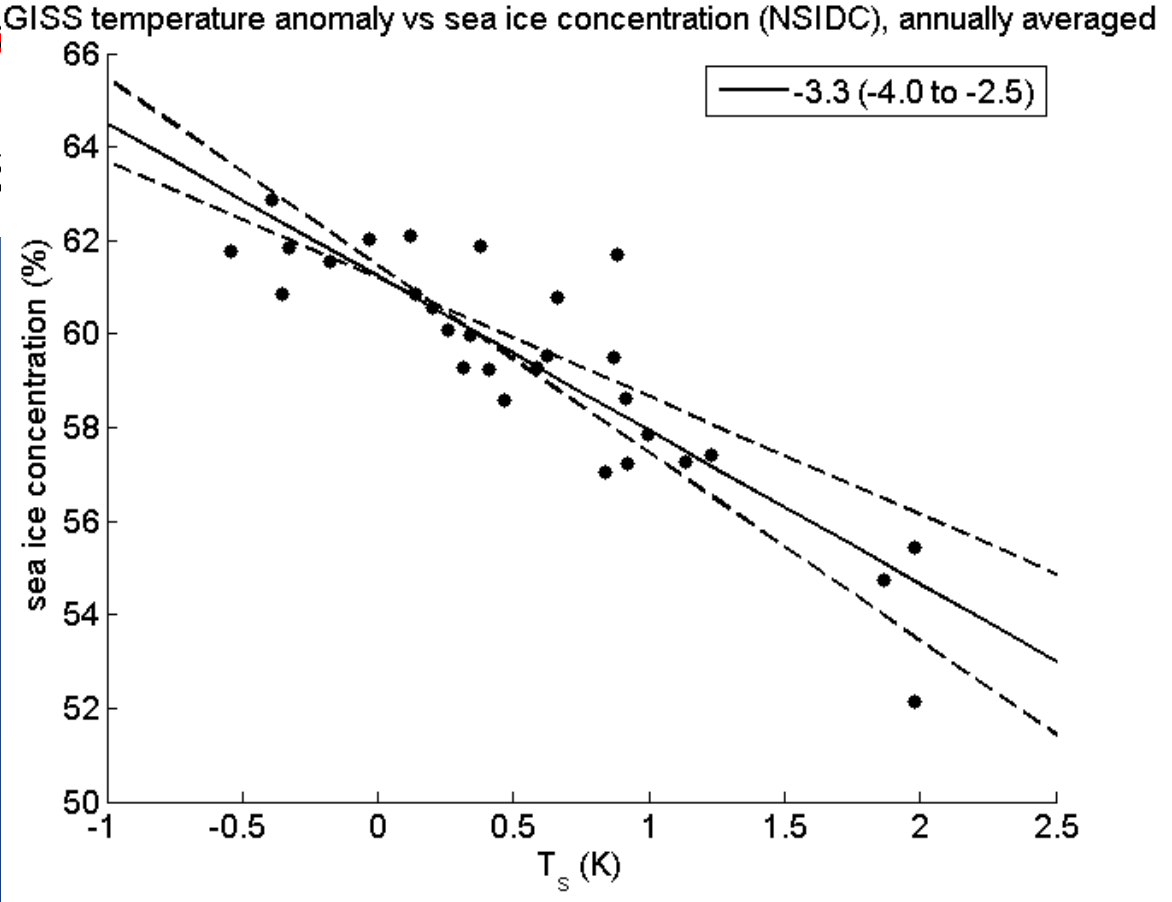
Feedbacks

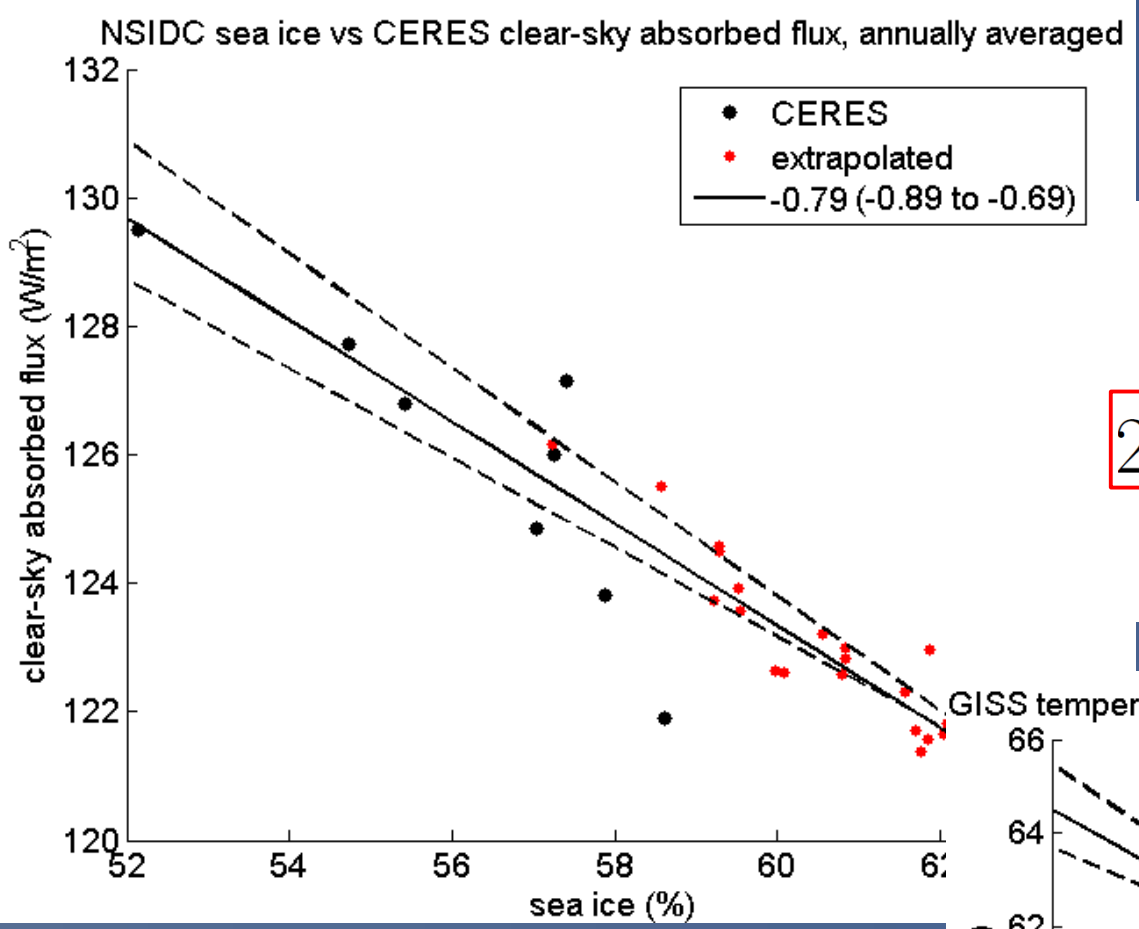
- Total arctic: linear least-squares fits to arctic as a whole
- By region: monthly best-fit to six sections, extrapolated, annual mean, total area mean
- Incorporate with local/hemispherical temperature changes: from GISS estimates
- Calculate dS/dT directly, and with dsi as an intermediate variable

$$\frac{dS_{abs}}{dT_s} \approx \left(\frac{dS_{abs}}{dsi}\right)\left(\frac{dsi}{dT_s}\right)$$


GISS temperature anomaly vs CERES clear-sky absorbed flux, annually averaged
CERES
extrapolated
2.7(2.1 to 3.3)
clear-sky absorbed flux (W/m2)
132
130
128
126
124
122
120
118
-1
-0.5
0
0.5
1
1.5
2
2.5
T_S (K)


NSIDC sea ice vs CERES clear-sky absorbed flux, annually averaged
CERES
extrapolated
-0.79 (-0.89 to -0.69)
clear-sky absorbed flux (W/m2)
sea ice (%)
132
130
128
126
124
122
120
52
54
56
58
60

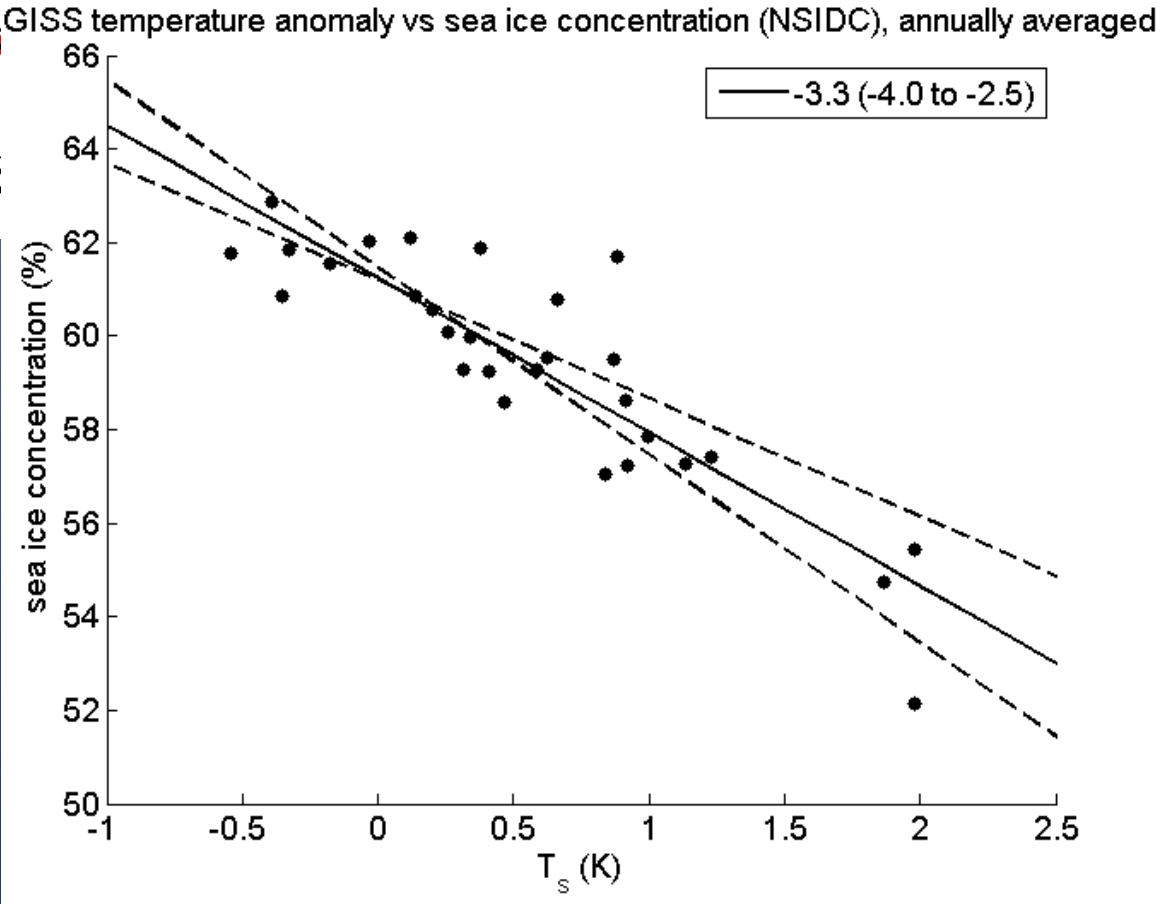

GISS temperature anomaly vs sea ice concentration (NSIDC), annually averaged
-3.3 (-4.0 to -2.5)
sea ice concentration (%)
T_S (K)
66
64
62
60
58
56
54
52
50
-1
-0.5
0
0.5
1
1.5
2
2.5



$$\frac{dS_{abs}}{dT_s} = \left(\frac{dS_{abs}}{dsi}\right)\left(\frac{dsi}{dT_s}\right)$$

$$2.7\ \mathrm{W/m^2/K} = -0.8 \cdot -3.3$$

$$= 2.6\ \mathrm{W/m^2/K}$$



Trends and Clear-Sky Feedbacks

Δ=1979-2007	Total Arctic	Regional Method
Over arctic ocean		
Δsea ice	-7.1%	-7.1 %
ΔS_{abs}	5.6 W/m^2	3.9 W/m^2
$\Delta T_{s,ac}$	2.0 K	2.0 K
For Northern Hemisphere		
$\Delta T_{s,NH}$	0.58 K	0.58 K
$\left(\frac{dS_{abs}}{dT_{s,ac}}\right)_{NH}$	0.17 W/m^2/K	0.13 W/m^2/K
$\left(\frac{dS_{abs}}{dT_{s,NH}}\right)$	0.42 W/m^2/K	0.31 W/m^2/K

Trends and Clear-Sky Feedbacks

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Δsea ice	-7.1%	-7.1 %
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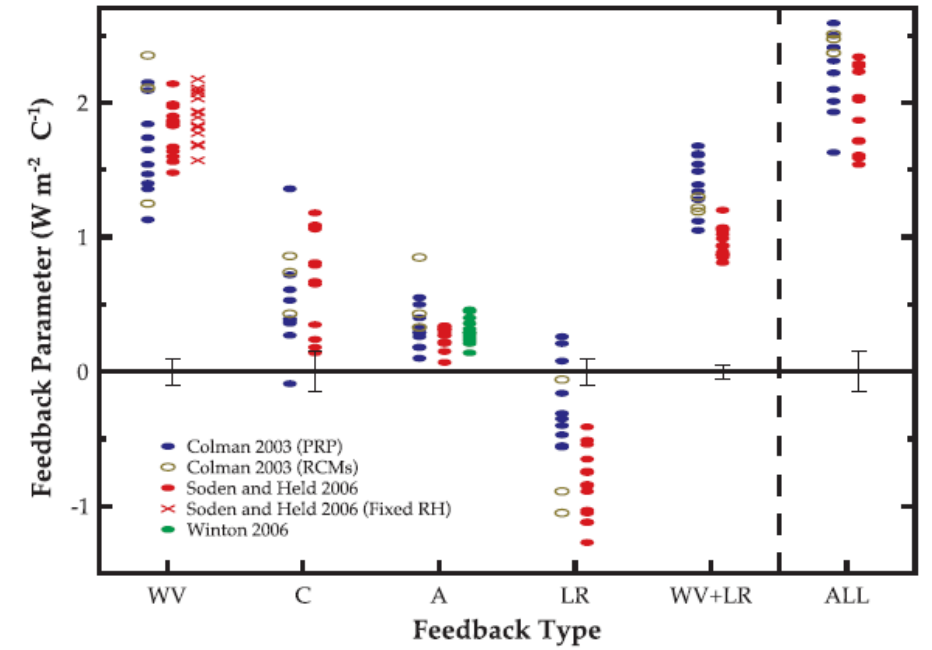
$\left(\frac{dS_{abs}}{dT_{s,NH}}\right)$	0.42 W/m^2/K	0.31 W/m^2/K

IPCC: 1.25-2W/m^2/K (global, all feedbacks)

Flanner et al 2011: 0.62W/m^2/K (NH cryosphere)



Summary

- Radiative effects of sea ice retreat show a strong spatial and temporal dependence, but a generally linear relationship for each
- Hemispherical clear-sky ice albedo feedback is ~0.3 $W/m^2/K$
- Sea ice retreat shows no signs of slowing, so it is imperative to quantify its effects to the best degree possible


Thank you!